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Development of MPMD System in Integrated Divertor Code
統合ダイバータコードSONIC におけるMPMD システムの開発

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With progressing each physical model in tokamak simulation codes, integrated code, e.g. coupling of a divertor code (SONIC: SOLDOR/NEUT2D/IMPMC) to a core transport code (TOPICS), has been developed. We introduced a new effective system on parallel computer for such integrated code, which is called MPMD (Multiple Program Multiple Data). This MPMD system has been further developed, i.e. parallel execution of Monte Carlo calculations and extension to a general-purpose system. We demonstrate the validity and usability of this system, applying to an integrated code which consists of very simple models to imitate TOPICS, SOLDOR, NEUT2D, IMPMC_C, IMPMC_Ar and OFMC code.

1. Introduction

Control of the power and particle exhaust is one of the most critical issues to achieve the tokamak fusion reactors. To investigate the control method by the divertor, we have developed a 2D divertor code, SONIC. The SONIC suite of integrated divertor codes [1] consists of the 2D plasma fluid code (SOLDOR), the neutral Monte-Carlo code (NEUT2D) and the impurity Monte-Carlo code (IMPMC). The feature of SONIC is that Monte-Carlo approach with flexibility of modelling is applied to impurity transport.

Since the core confinement and the divertor characteristics are significantly affected each other, SONIC has been consistently coupled to a tokamak transport code (TOPICS). To integrate TOPICS and SONIC, we introduced a new effective system on parallel computer, which is called MPMD (Multiple Program Multiple Data) approach [2]. This MPMD system has been further developed, i.e. parallel execution of Monte-Carlo calculations and extension to a general-purpose system.

2. MPMD system

The SONIC simulations were performed by a single large load module, which is called Single Program Multiple Data (SPMD). The load module which contains SOLDOR, NEUT2D and IMPMC are executed on all PEs (process element). Including all common variables, a load module becomes very huge when several impurities are treated. In addition, extension and improvement of the each code become hard task because the codes are closely connected. On the parallel computer, the integrated code which consists of multiple load modules, can be executed with exchanging data between load modules. Schematic of self-consistent integrated modelling of core and SOL/divertor transports is shown in Fig. 1.

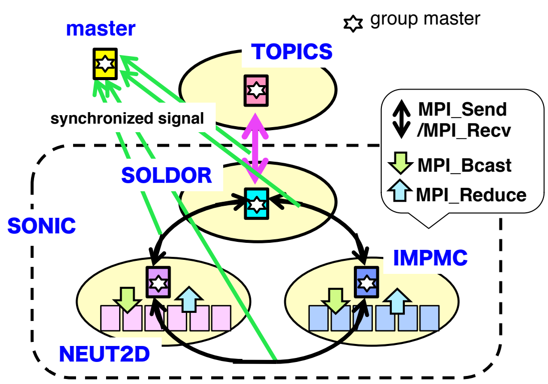

Fig. 1 MPMD parallel computing system for the integrated modelling of 1.5D core transport (TOPICS) and 2D SOL/divertor transport (SONIC). Exchanging data between codes is performed between MPI rank 0 process (group master) in each code.

The mutual interface between codes is limited to exchange data through MPI_Send/MPI_recv routines (Massage Passing Interface). This loose coupling based on MPMD makes it possible to improve independently each component of the integrated code without interference in each other.

The sequence control of code execution and exchanging data between codes is described a external file. The role of grand-master PE is only to synchronize between group masters. The MPMD system became a general-purpose system by this scheme. Figure 2 illustrates an example of "code spec. file" In the exec step, codes of ofmc, neut2d and impmc are executed in parallel, followed by soldor, by topics. The impmc code needs the MPI data type of TOK, DIV and NTL. They are produced by topics, soldor and neut2d, respectively. After the execution of impmc, the new MPI data type IMP and FLX are produced.

```
comt : define Data Flow between Codes
code : master topics soldor neut2d impmc ofmc
time : topics

dtyp : TOK       topics
dtyp : DIV       soldor
dtyp : NTL       neut2d
dtyp : IMP       impmc

exec 1 : ofmc     TOK              => NBI
exec 1 : neut2d   TOK NBI          => NTL
exec 1 : impmc    TOK DIV NTL      => IMP FLX
exec 2 : soldor   TOK IMP NTL      => DIV
exec 3 : topics   DIV NTL IMP      => TOK
```

Fig. 2 A code spec. file describes the order of execution codes and exchanging data between codes

3. Application to Integrated Code

We demonstrate the validity and usability of this system, applying to an integrated code which consists of very simple models to imitate TOPICS, SOLDOR, NEUT2D, IMPMC_C, IMPMC_Ar and OFMC code. In the core transport model (TOPICS), the particle number N and the stored energy W is simply modeled as follows;

$$\frac{dN}{dt} = -\frac{N}{\tau_N} + S_N + S_{NBI}, \qquad (1)$$

$$\frac{dW}{dt} = -\frac{W}{\tau_W} + P_{OH} + P_{NBI} - P_{rad} \qquad (2)$$

The plasma density and temperature at the center (N_0, T_0) is determined from (N, W) with an assumption of fixed profiles. The confinement times are individually given as input parameters according to phase (OH, L-mode and H-mode phase). The L→H transition occurs when T_e at x = 0.95 reaches 0.8 keV. The plasma parameters at the mid-plane (x=1.0) are determined by a 2-point divertor model [3] instead of soldor code. The particle and heat fluxes into the SOL region are evaluated by $\Gamma_{sol} = N/\tau_N$ and $Q_{sol} = W/\tau_W$.

Simulations are carried out for a full current drive operation of JT-60SA with $I_p = 2.3\,MA$, $B_T = 2.3\,T$, $\beta_N = 4.3, f_{BS} = 71\%, P_{in} = 41\,MW$. The L→H transition occurs occurs at t = 1.57 sec and the density control to keep the plasma density at the center $N_0 = 8\times10^{19}\,m^{-3}$ starts at t = 3.2 sec. At the steady state t = 4.0 sec, the plasma parameters are as follows; $T_d = 20\,eV, N_d = 1.2\times10^{20}\,m^{-3}, T_{es} = 130\,eV, T_{is} = 270\,eV, N_s = 2.7\times10^{19}\,m^{-3}$. The peak heat flux onto the divertor plate is around $12\,MW/m^2$. These parameters agrees fairly well with the results obtained by SONIC simulations. The L→H transition, the density control and impurity control due to Ar puff are performed just as intended. The validity of the MPMD system are verified.

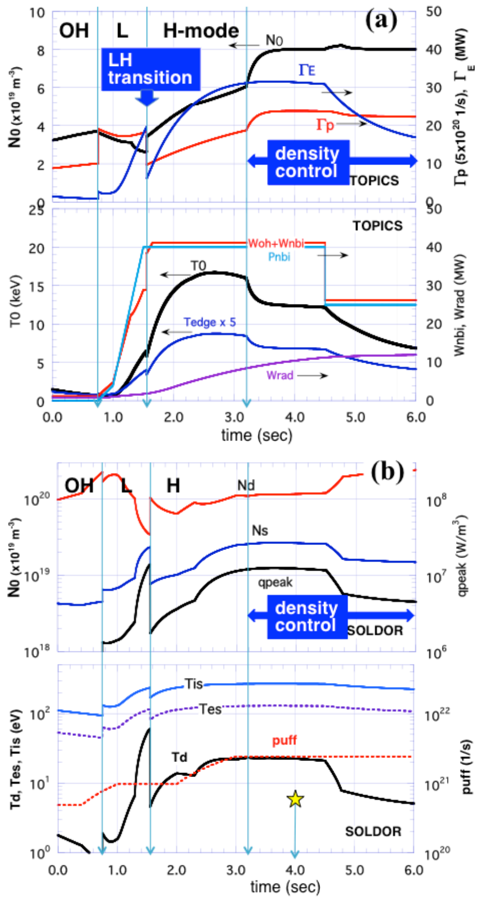

Fig. 3 (a) TOPICS code calculates N_0 *and* T_0 at the plasma center. (b) SOLDOR code (2-point divertor model) calculates N_d, T_d at the divertor plate and N_s, T_{is}, T_{es} at the SOL.

Acknowledgments

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References

[1] K. Shimizu, T. Takizuka. et al 2009 Nucl. Fusion **49** 065028.

[2] A. Takayama, K. Shimizu, et al., J. Plasma Fusion Res. SERIES **9** (2010) 604.

[3] K. Shimizu, T. Takizuka. J. Plasma Fusion Res. **80** (2004) 183.